Relating Head Measurements to Fit and Comfort of Helmets

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ISSC Conference
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U.S. Army Project:
Future Force Warrior (FFW)

Lead Technology Integrator (LTI):

Eagle Enterprise, A General Dynamics Company

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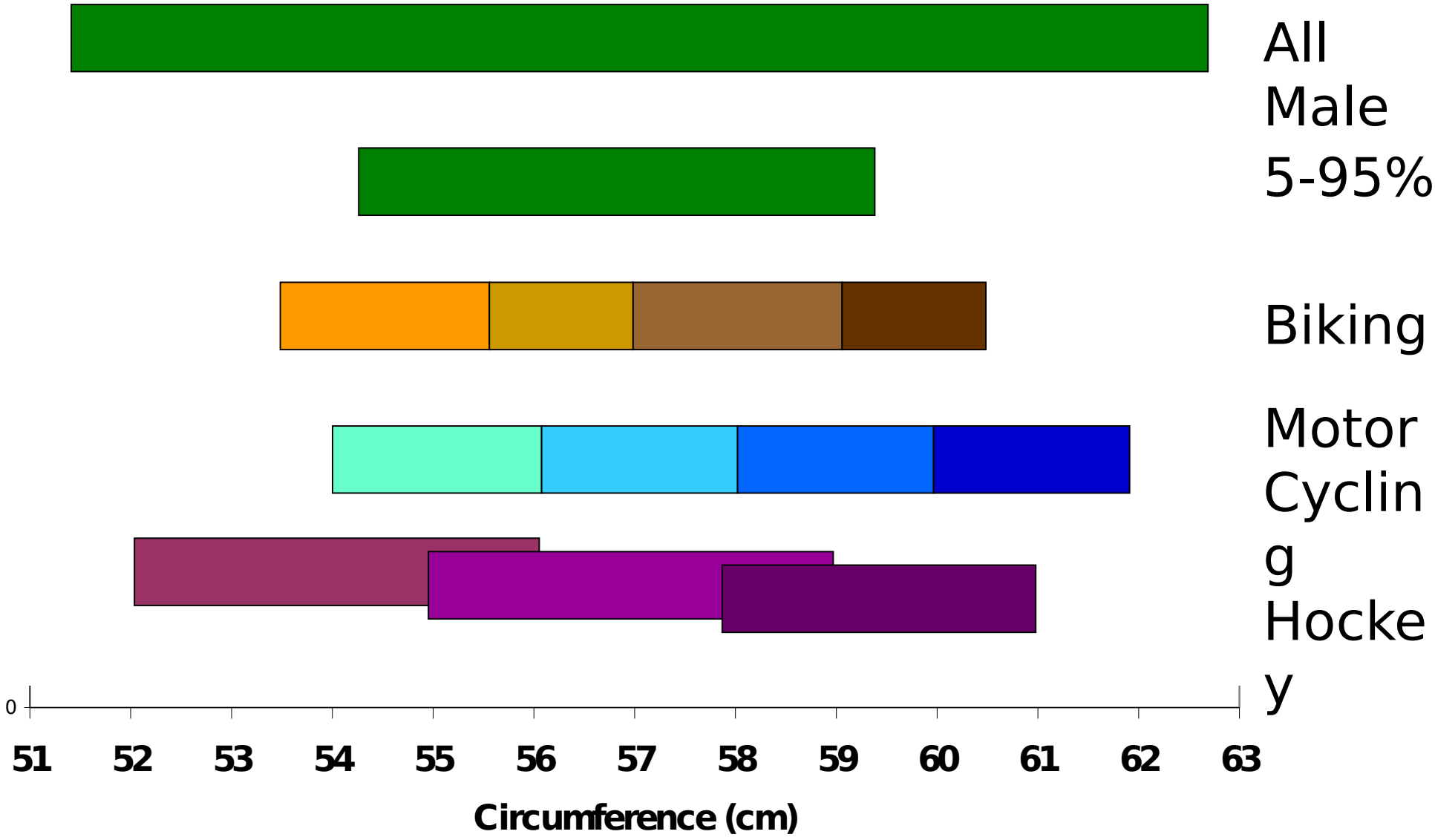
New Capabilities

- Head-mounted-display
- Multi-spectral sensors for enhanced vision
- Communications support
- Eye and ear protection

Tough Constraints

- Similar or better ballistic protection
- Improved impact protection
- More stable retention system as platform for the sensors and displays
- Strict weight restrictions
- Accommodating wide range of head sizes and shapes

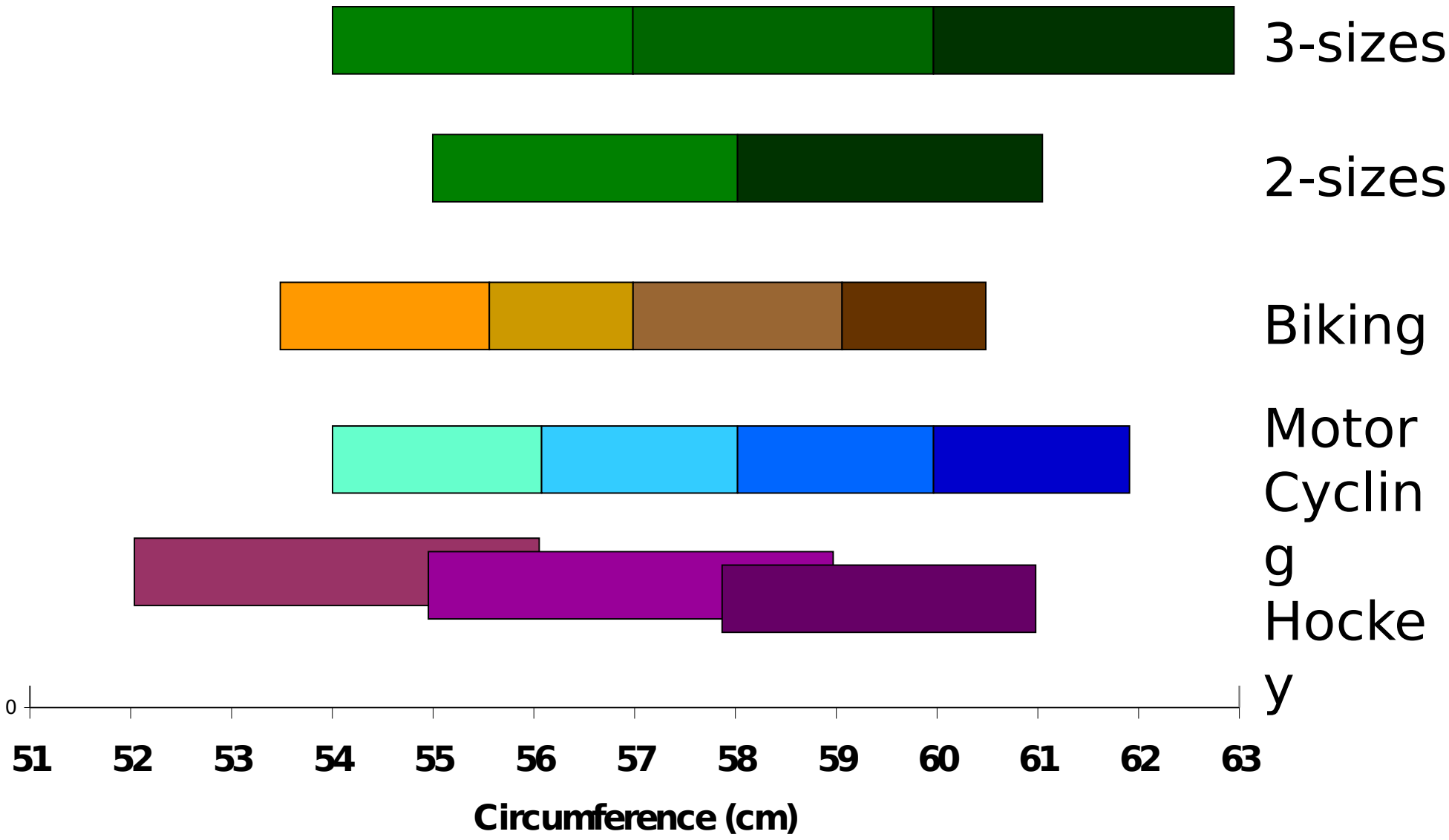
Popular Adult Sizing Schemes



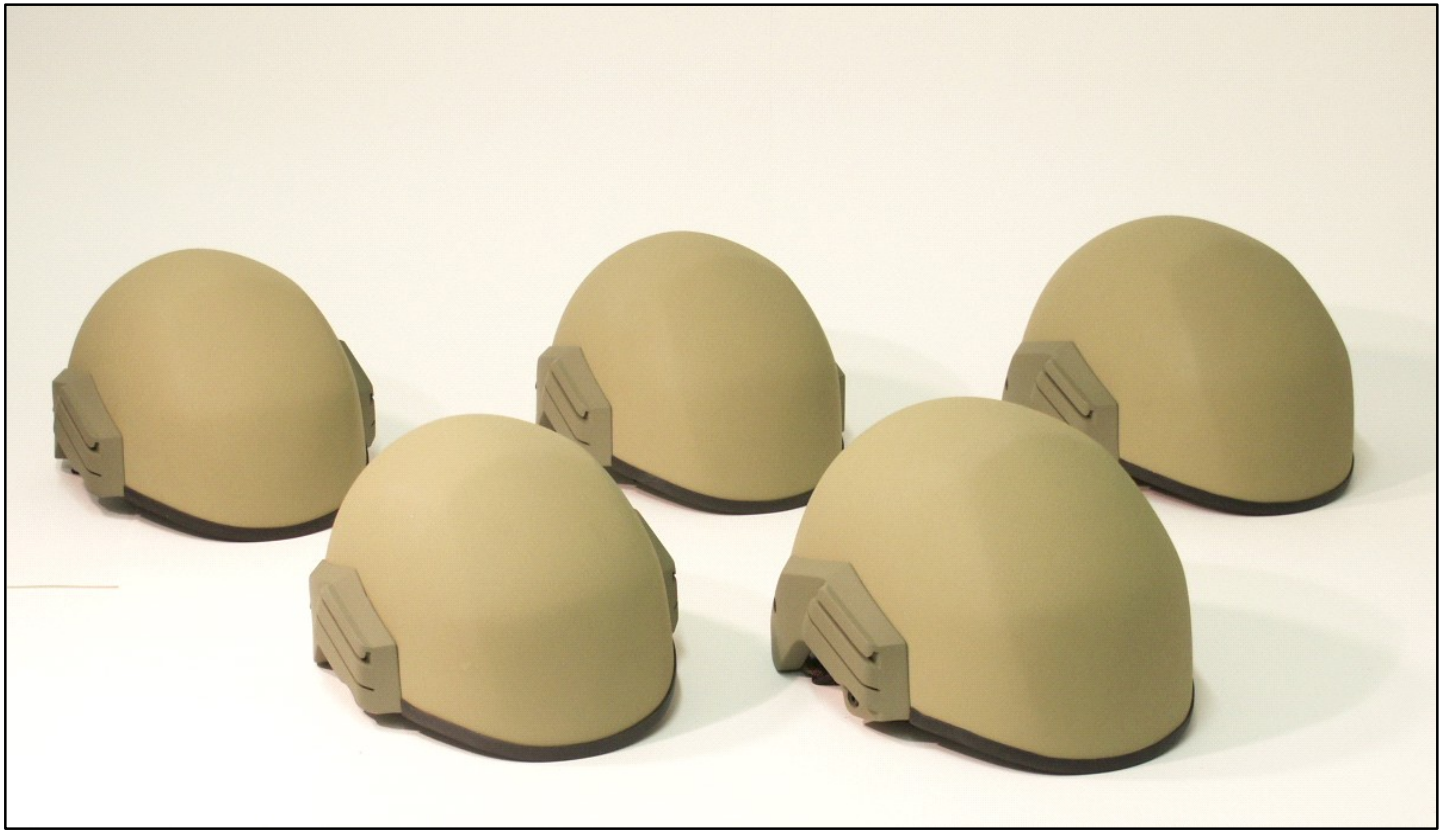
ANSUR 88 Male
Working Data (N = 1774)

- Circumference 51.4 – 62.7 cm
- Width 128 – 173 mm
- Length 173 – 220 mm
- Initial request: 5-95%
  - Two sizes 55-58; 59-62
  - Three sizes 54-57; 57-60; 60-63

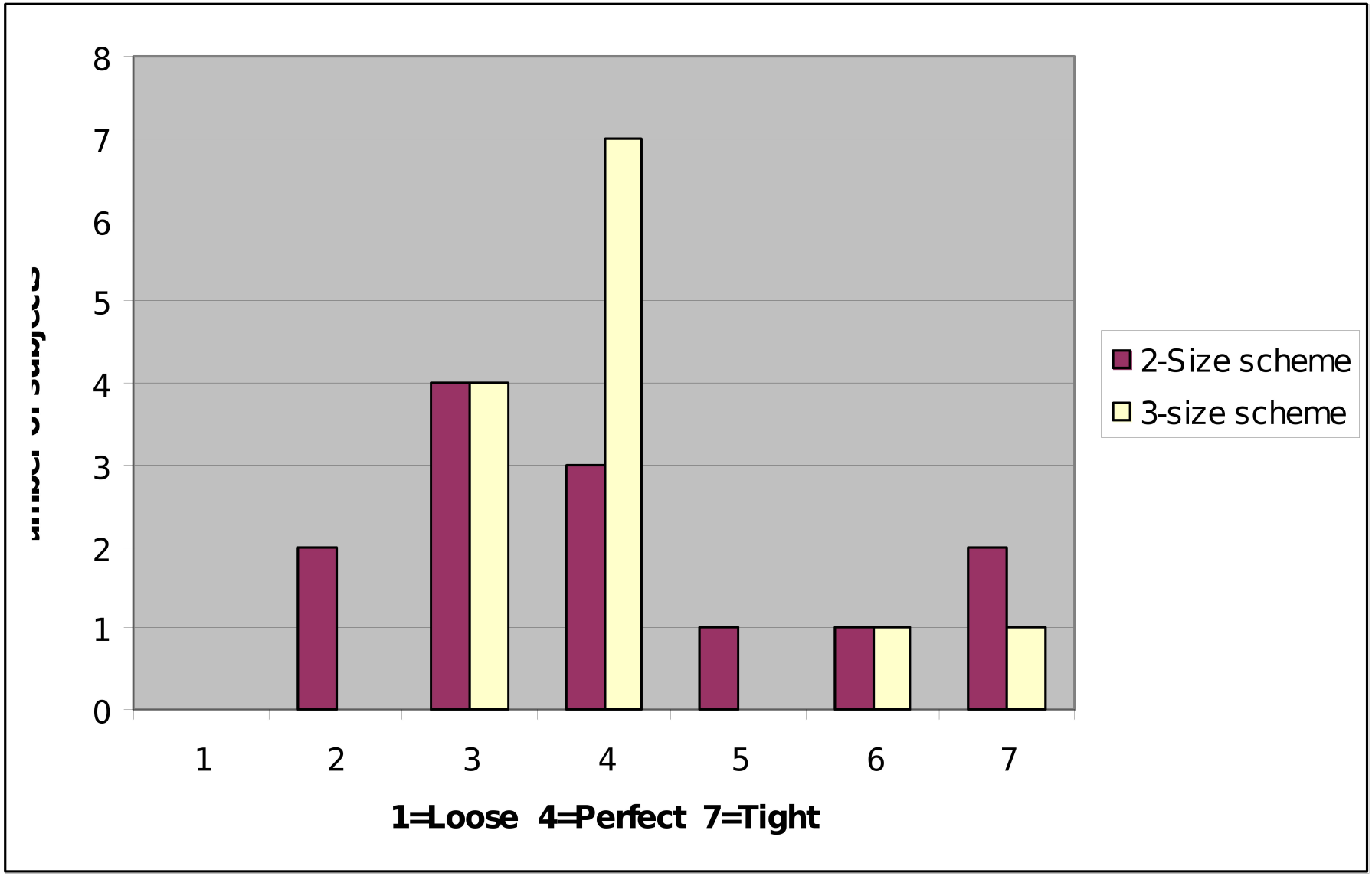
Two vs Three Sizes



Fit Models of 2 vs 3 Sizes



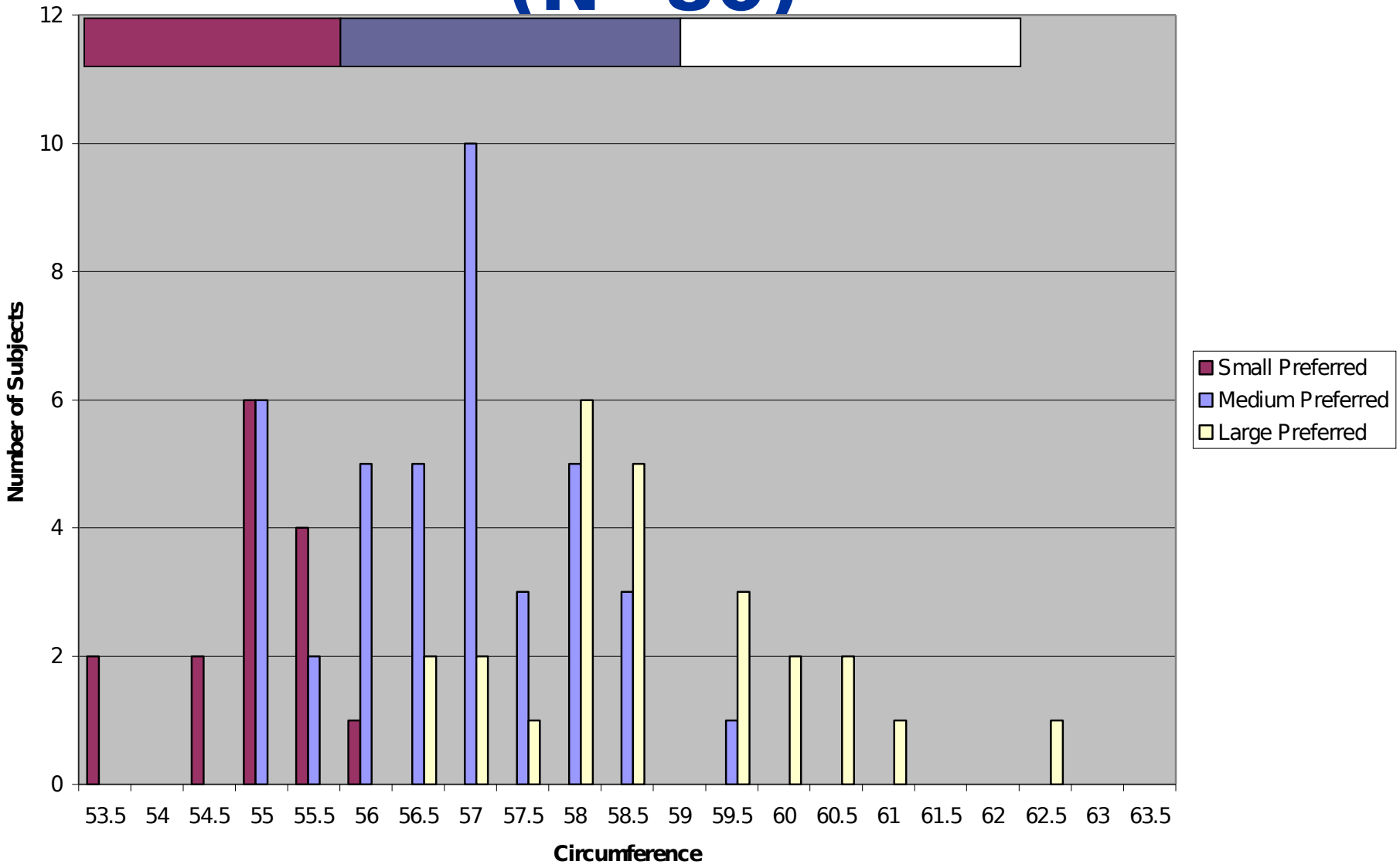
User Jury Feedback (N=13)



Decision

- Three sizes
  - cover 5-99+ percentile males
- Avoid need for extra-large
- Addition of extra small will cover females with total of 4 helmets

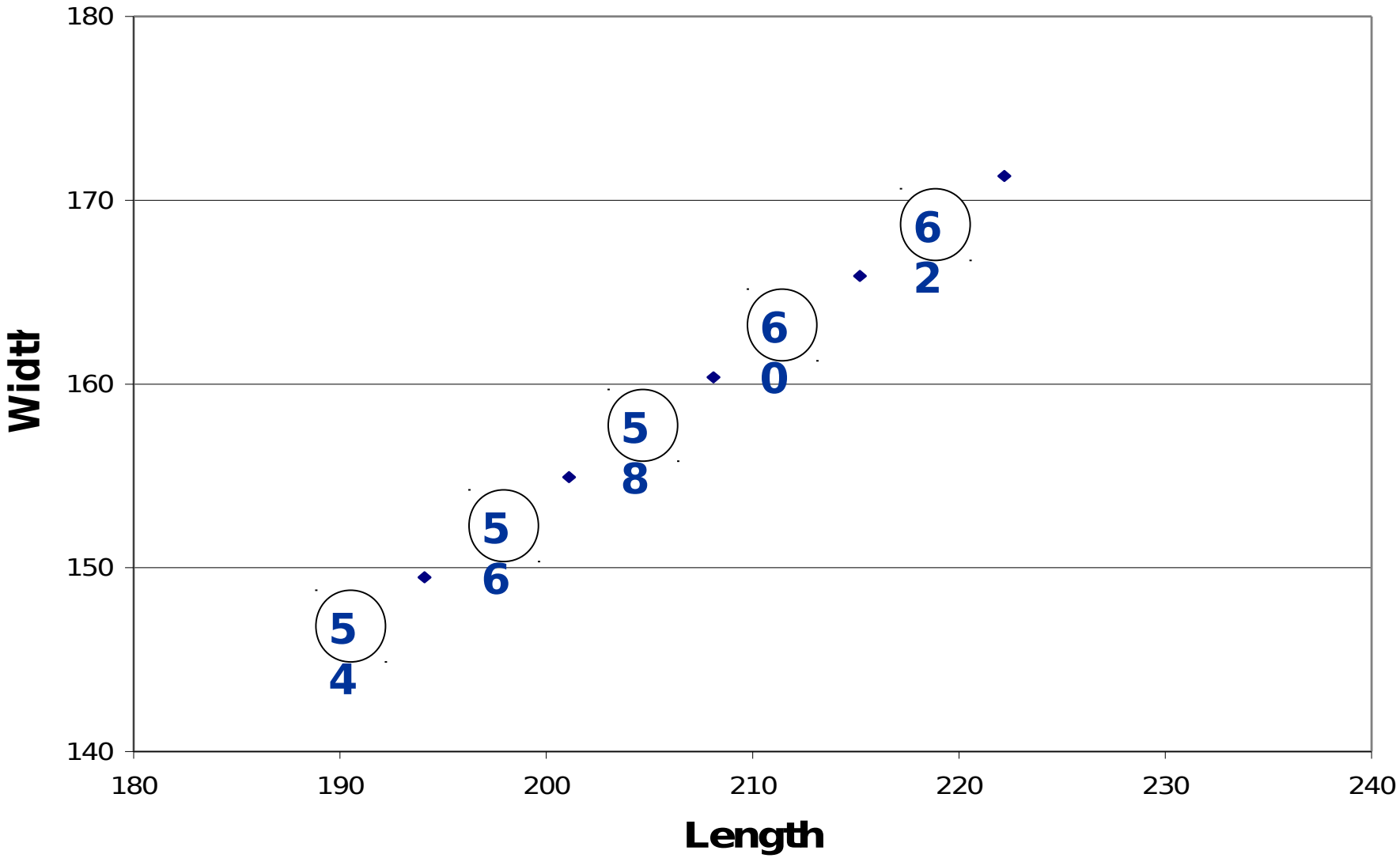
Preferred Lacrosse Helmet (N=80)



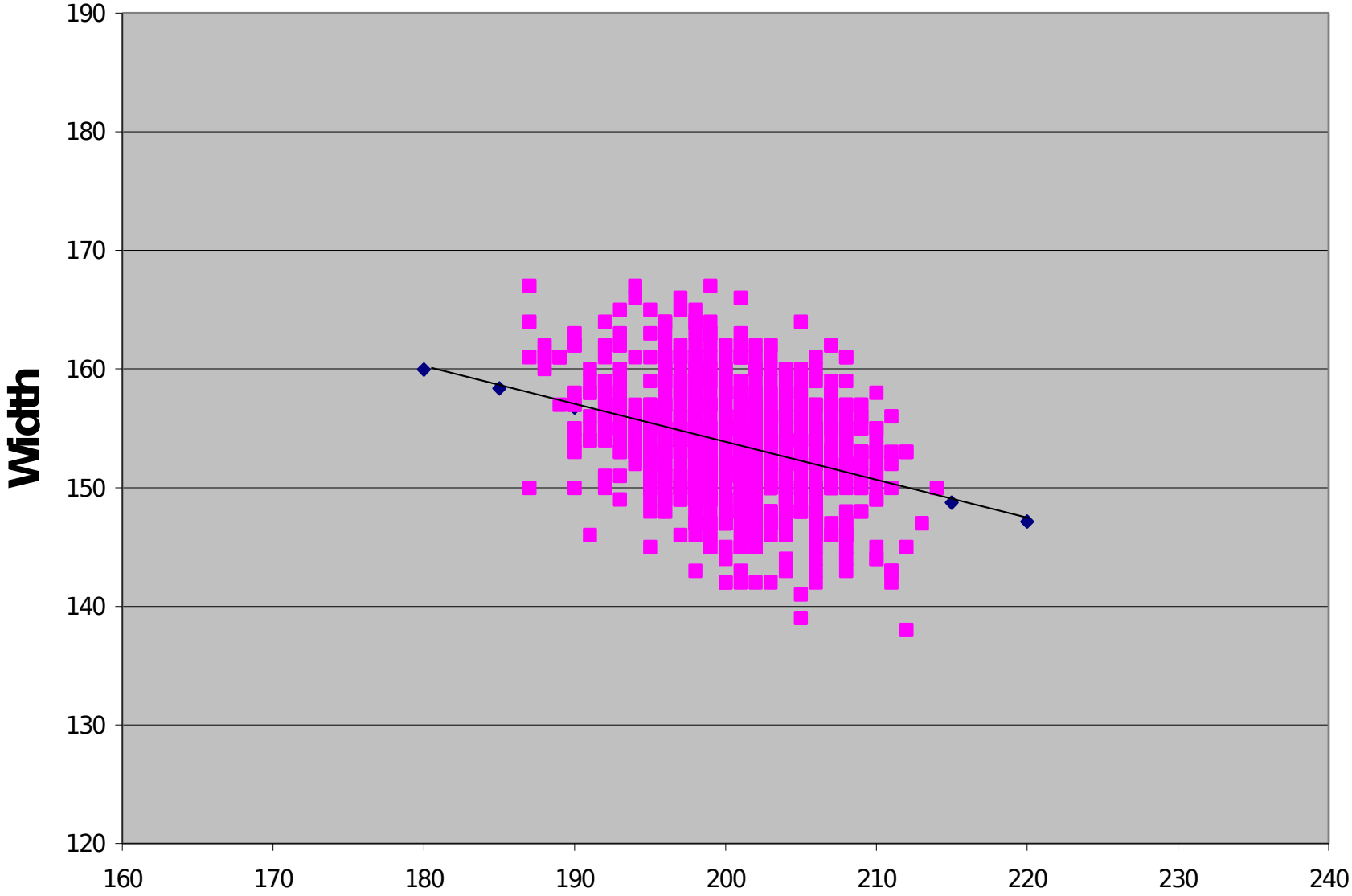
Sizing by Circumference

- Measured Circumference predicted preferred helmet size correctly only 67.5% of the time.
- Why?

Typical view of Head Sizing



Medium Circum. 56.6 – 59.5 cm



ANSUR 88 Male Working Data N = 1774

- Correlations:
  - Width vs. Length 0.12
  - Width vs. Circum. 0.54
  - Length vs. Circum. 0.82
  - Circum vs Length+Width 0.93

Ft Benning study (N = 74)

Soldier #	Age	Gen 1 = M 2 = F	Ethn	Length	Width	Depth	Circum	Depth 1 Ear top to shell edge	Depth 2
23	24	1	1	192	150	116	562	22	12
24	36	1	1	207	146	102	580	3	7
25	30	1	1	193	155	100	570	5	12
26	25	1	1	210	155	106	590	3	7
27	24	1	1	188	143	97	545	3	1
28	35	1		193	150	102	560	17	5

Helmet 1 1 = Sm 2 = Med 3 = Lg	Hel 1 liner 1 = Thick 2 - Thin	Helmet 1 scores Length 1=loose 7=tight	Width 1=loose 7=tight	Depth 1=shallow 7=deep	Comfort 1=Uncomf 7=Vr com	Helmet 2 1 = Sm 2 = Med 3 = Lg	Hel 2 liner 1 = Thick 2 - Thin	Helmet 2 scores Length 1=loose 7=tight	Width 1=loose 7=tight	Depth 1=shallow 7=deep	Comfort 1=Uncomf 7=Vr com	Preferred Helmet 1 = Hel 1 2 = Hel 2
1	2	4	6	4	3	2	1	4	4	4	4	2
2	1	2	3	4	5	1	2	6	6	1	2	1
2	1	3	3	5	4	1	2	5	5	3	5	2
2	2	4	2	4	5	2	1	4	4	4	6	2
1	1	3	6	4	3	1	2	4	4	4	4	2
1	2	7	7	1	1	2	1	3	3	3	5	2

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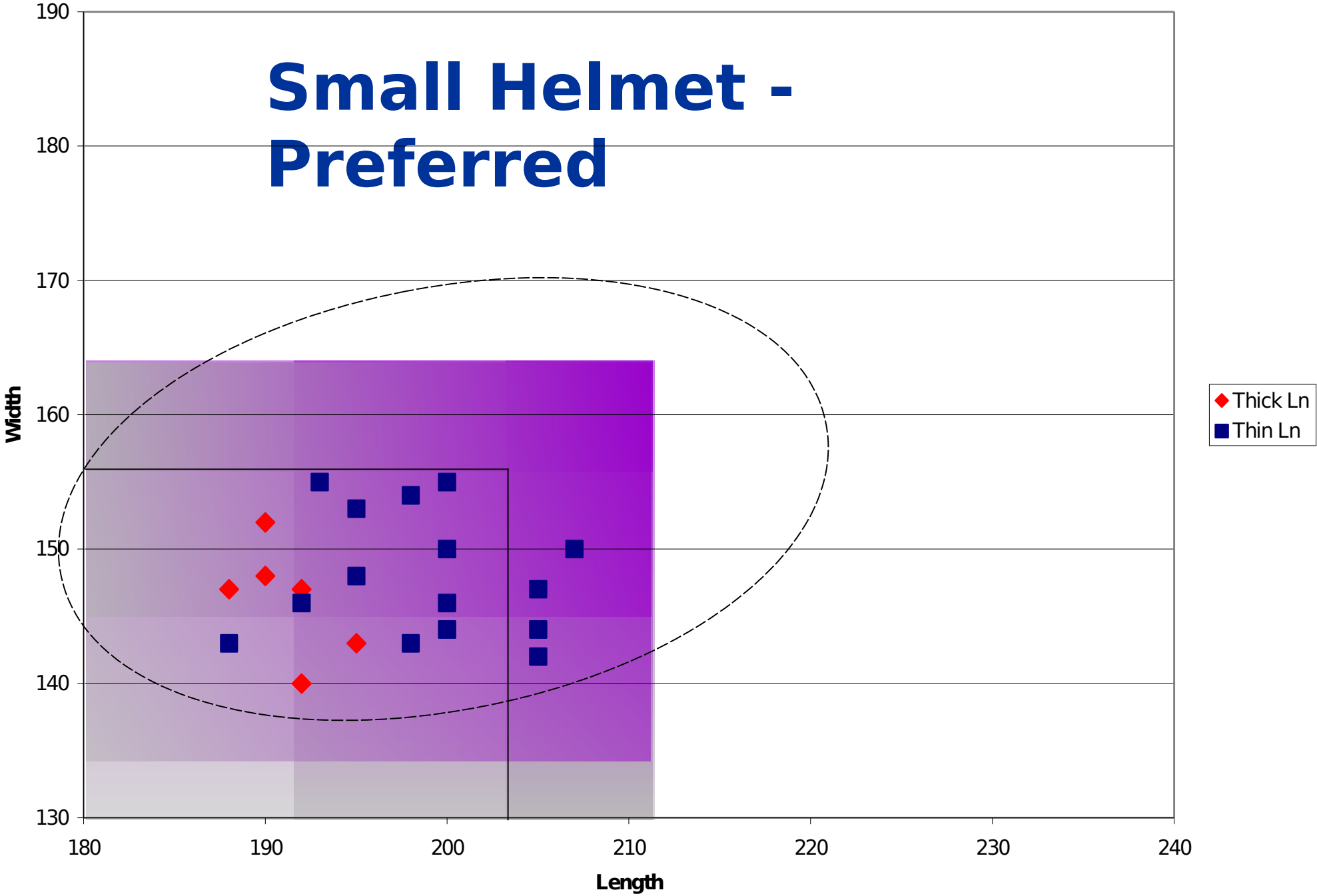
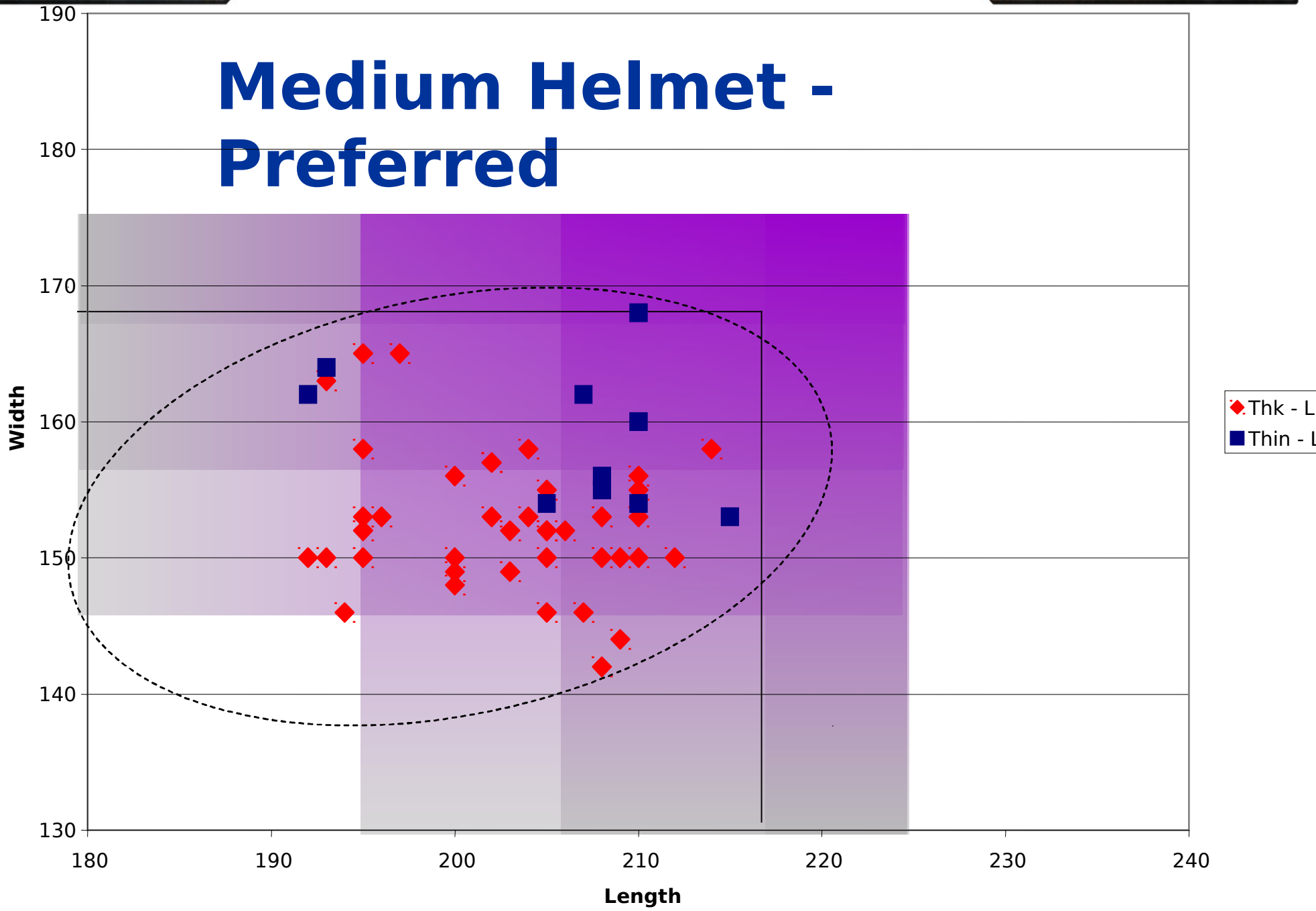
Small Helmet - Preferred



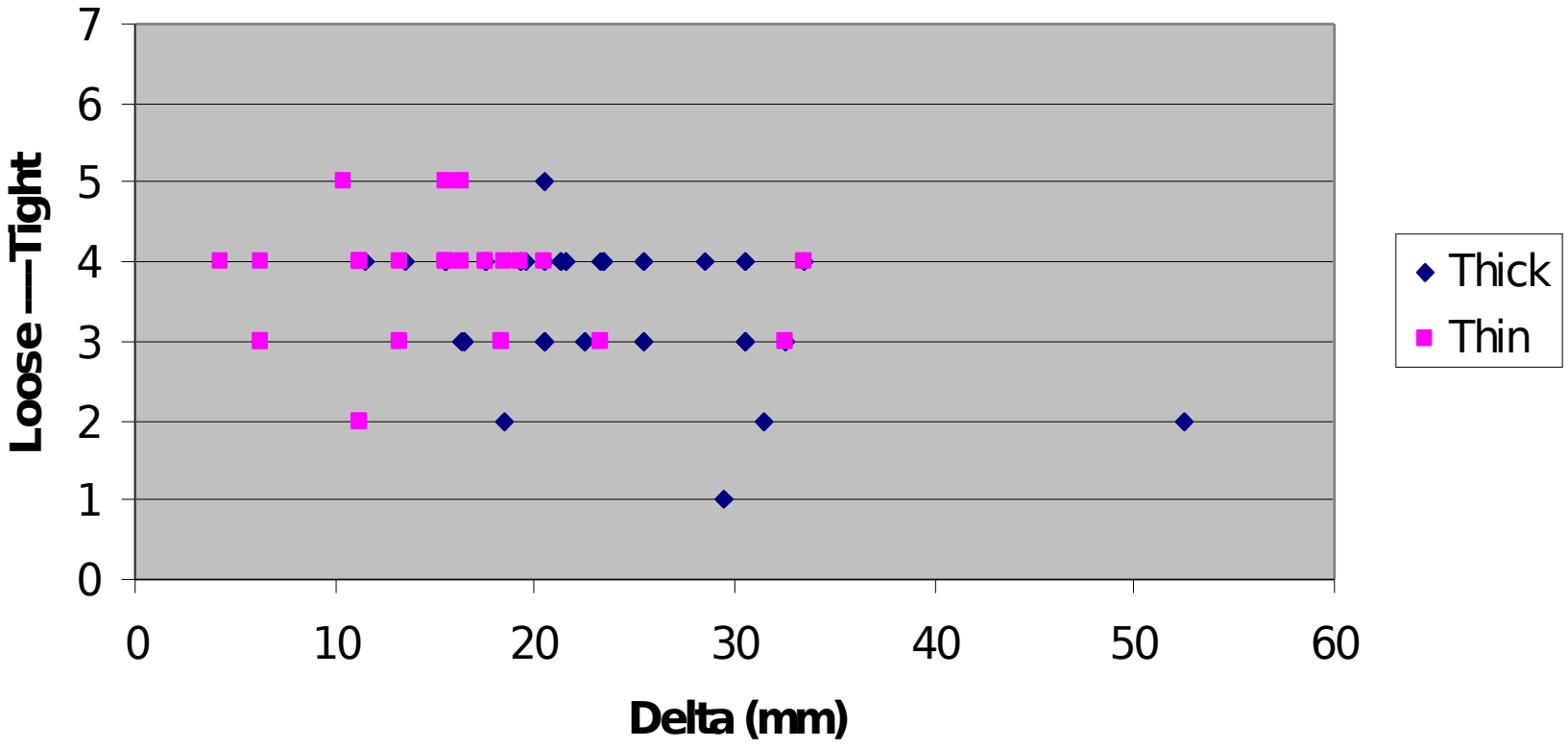
Medium Helmet - Preferred



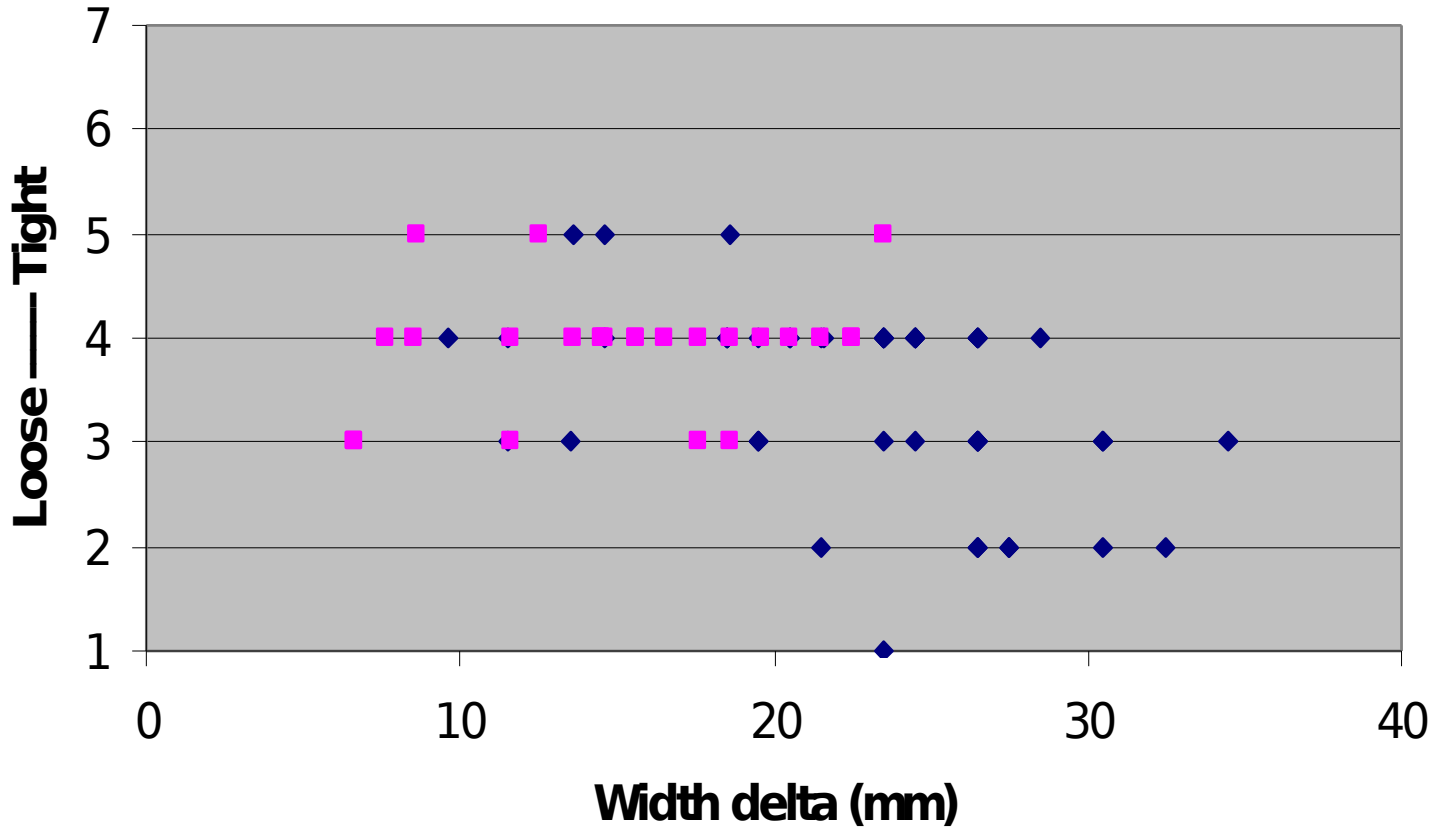
Predicting Helmet Size by Length and Width measurements

	Predicted				
Actual	**Small**	**Medium**	**Large**	**Total**	**% Correct**
Small	12	9	0	21	57.1
Medium	7	43	1	51	84.3
Large	0	1	1	2	50.0
Total	19	53	2	74	**75.7**

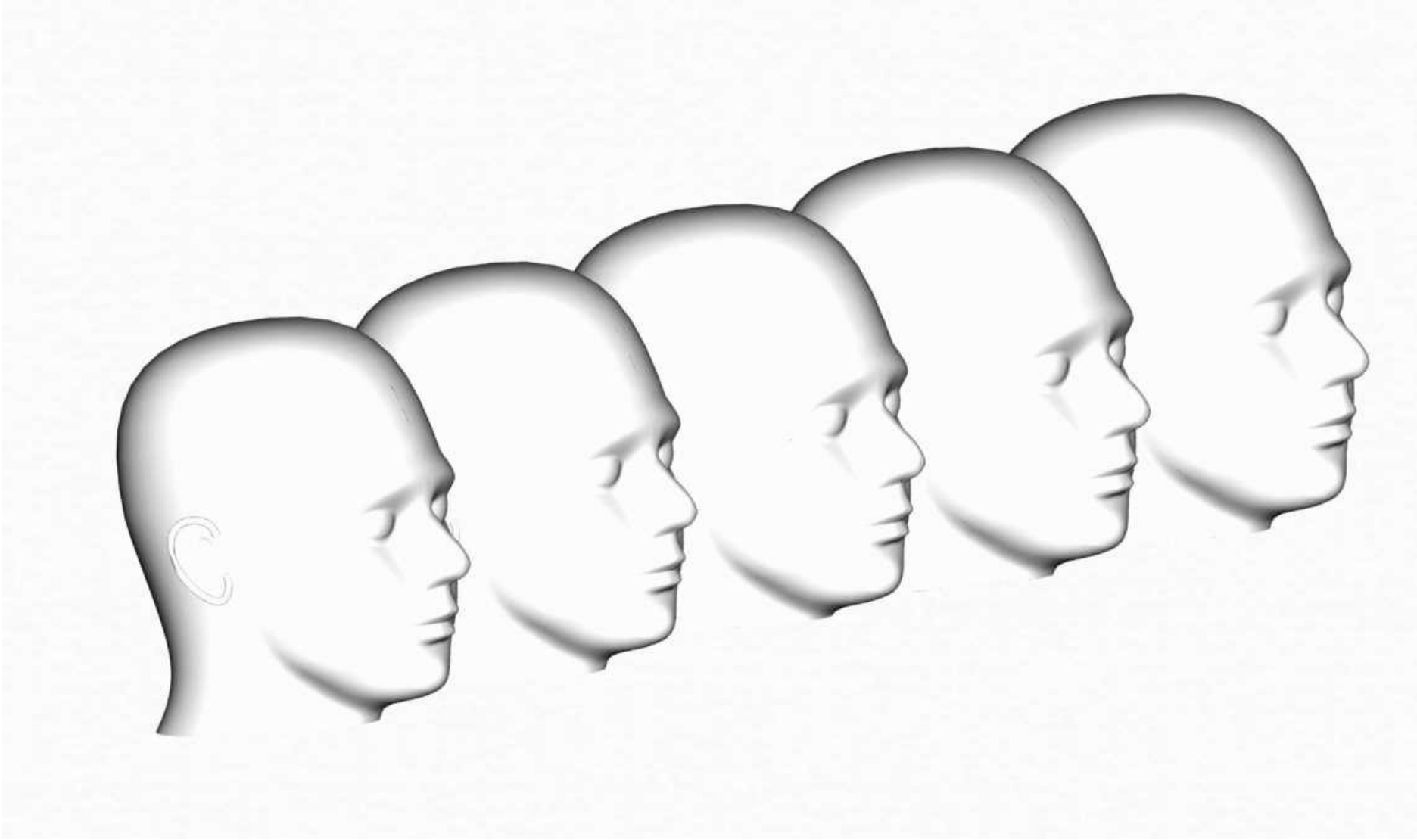
Preferred Delta (Length)



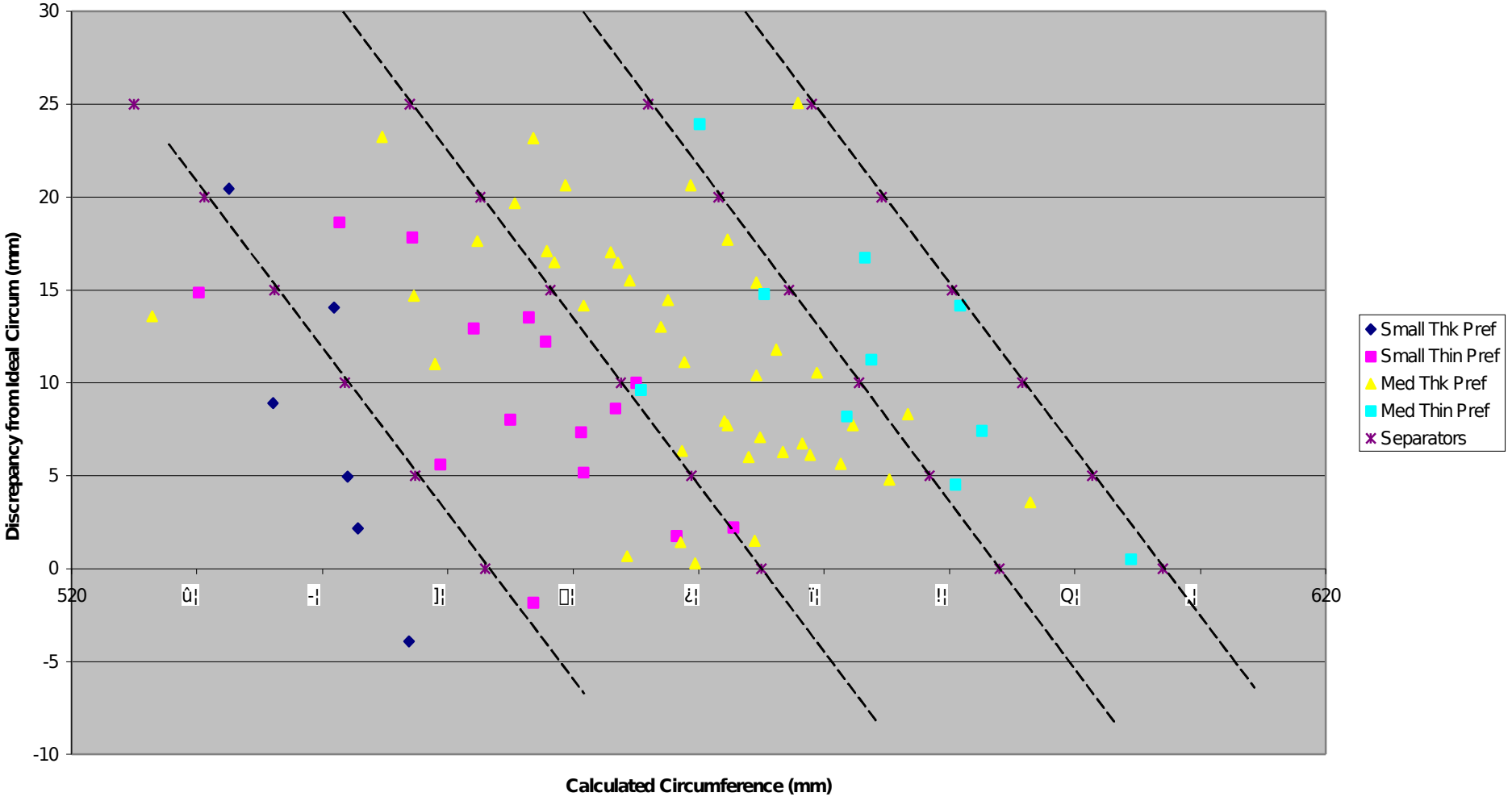
Preferred Delta (Width)



Assumptions about Shape



Shape Discrepancy (N=74)



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Predicting Helmet Size by Shape Discrepancy calculations

	Predicted				
Actual	**Small**	**Medium**	**Large**	**Total**	**% Correct**
Small	19	2	0	21	90.5
Medium	8	43	0	51	84.3
Large	0	0	2	2	100.0
Total	27	45	2	74	**86.5**

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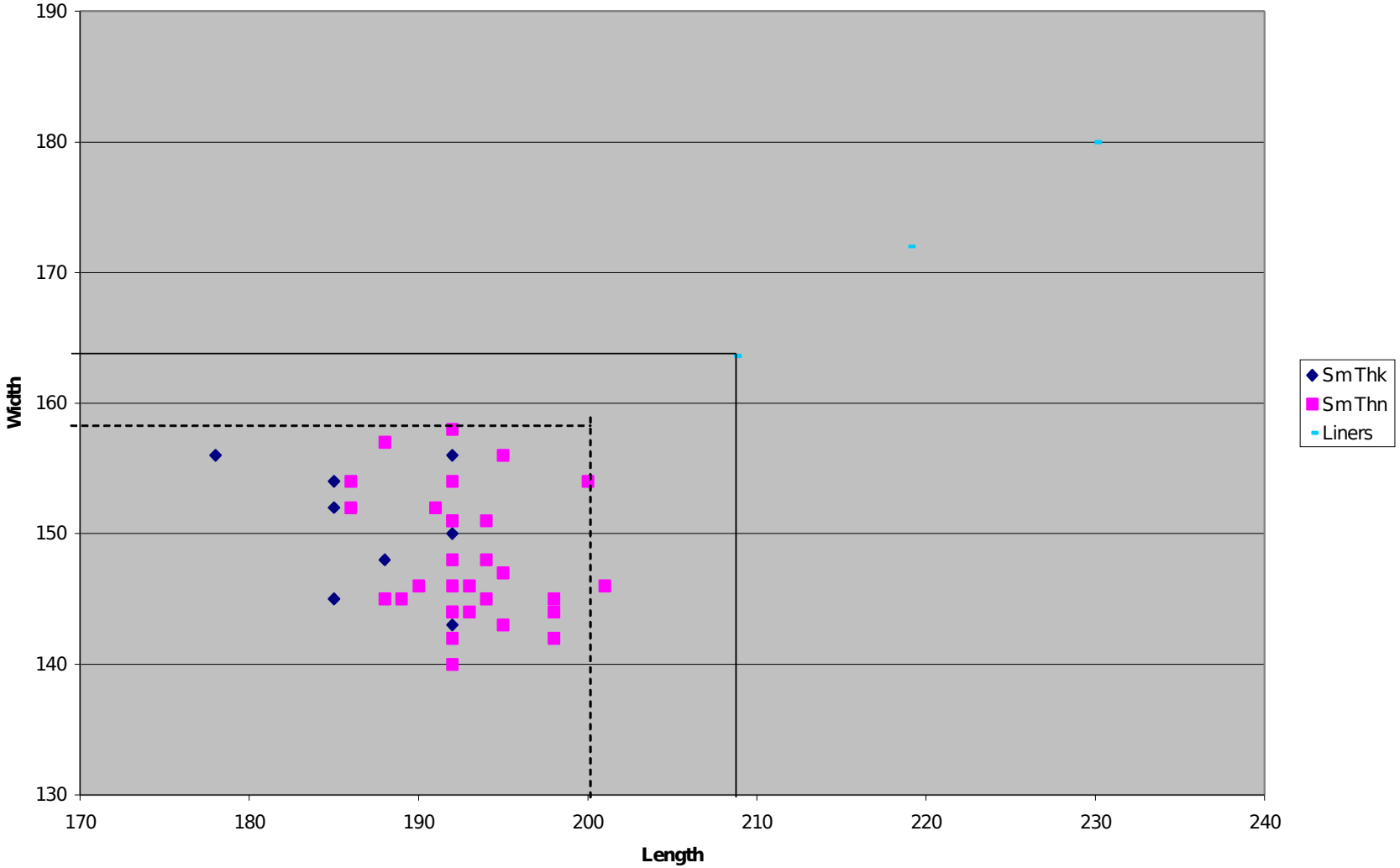
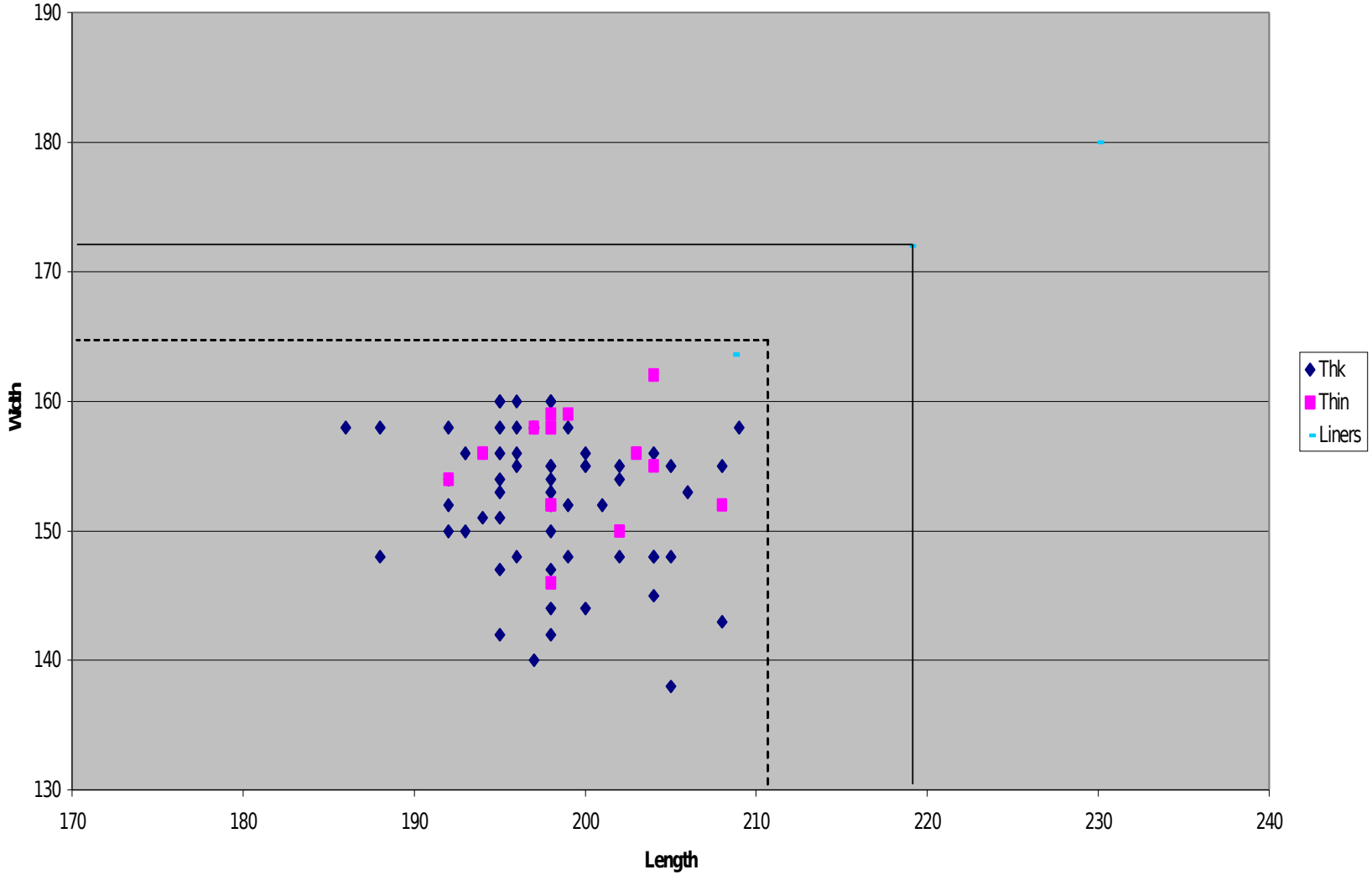
Small Helmet Preferred



Medium Helmet Preferred



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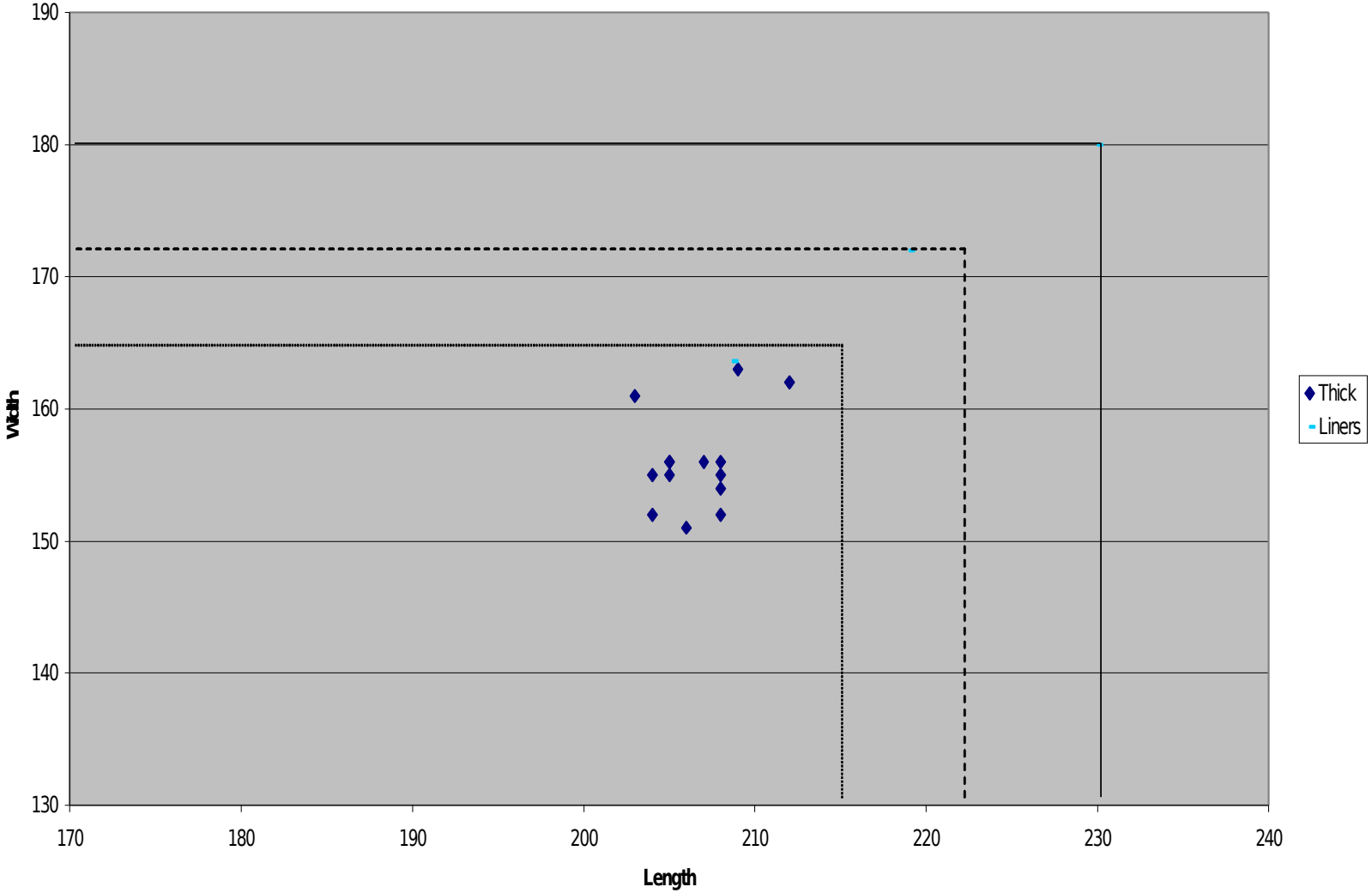
Large Helmet Preferred



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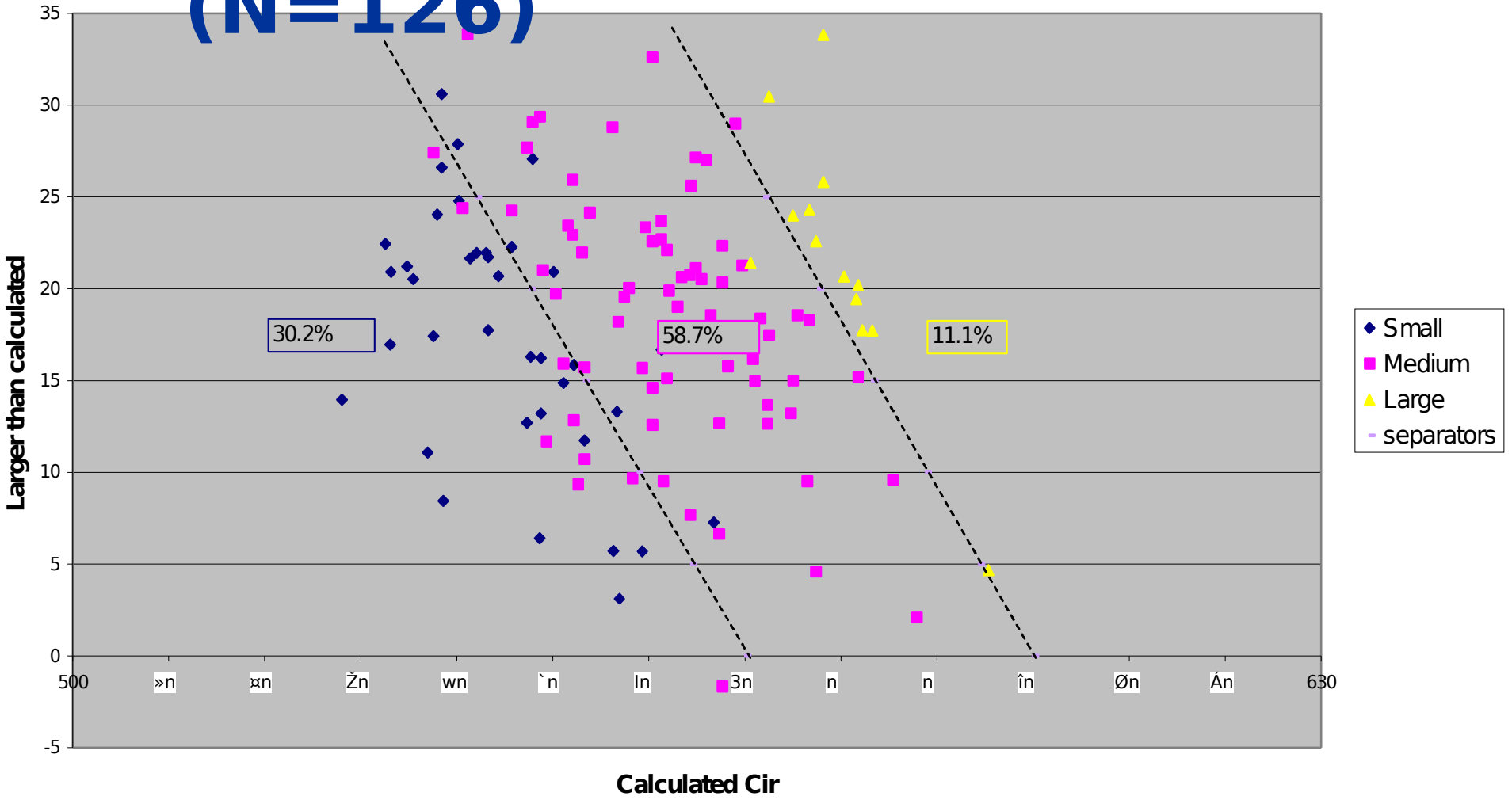
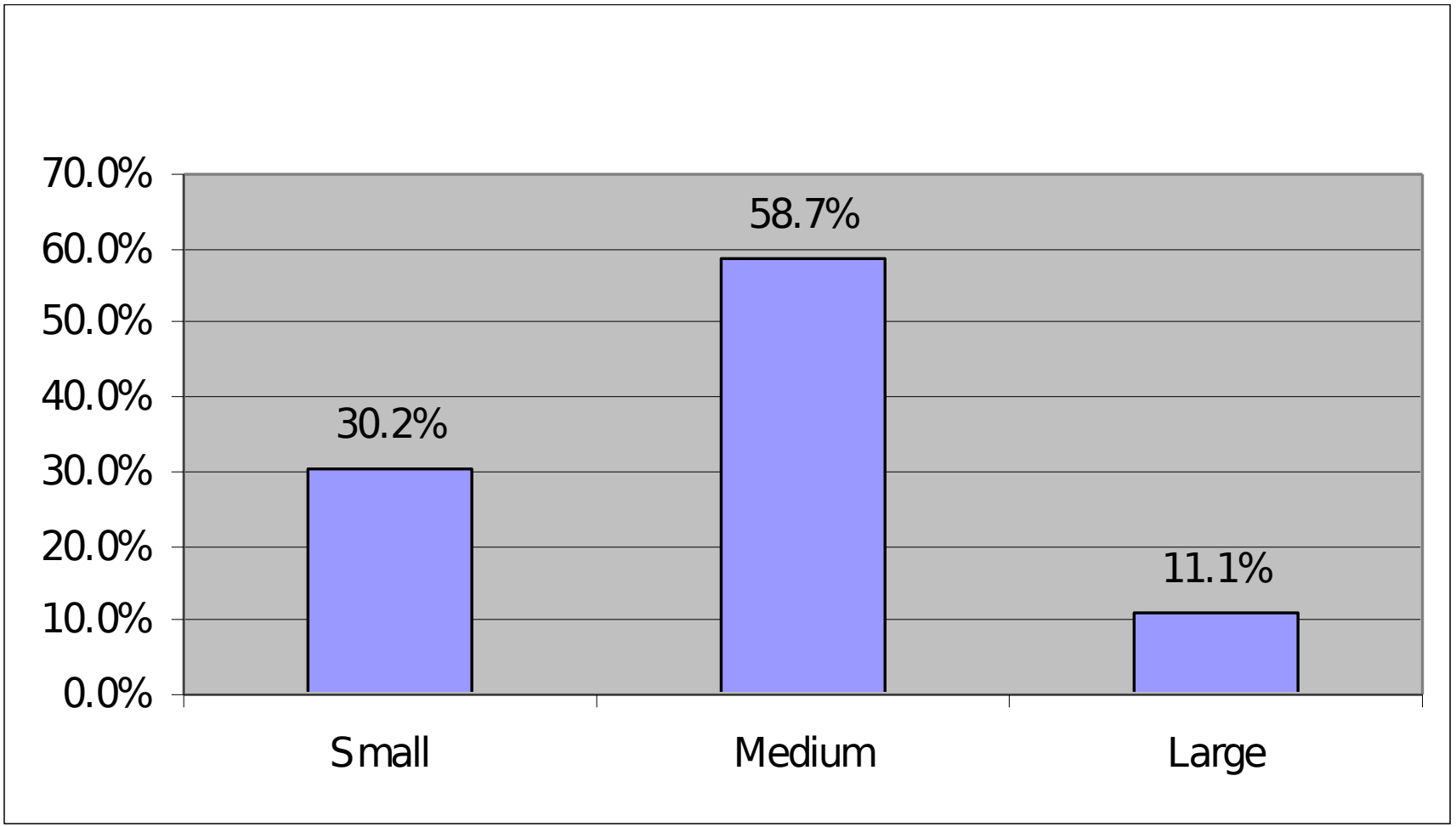
Shape Discrepancy applied to new sizes (N=126)



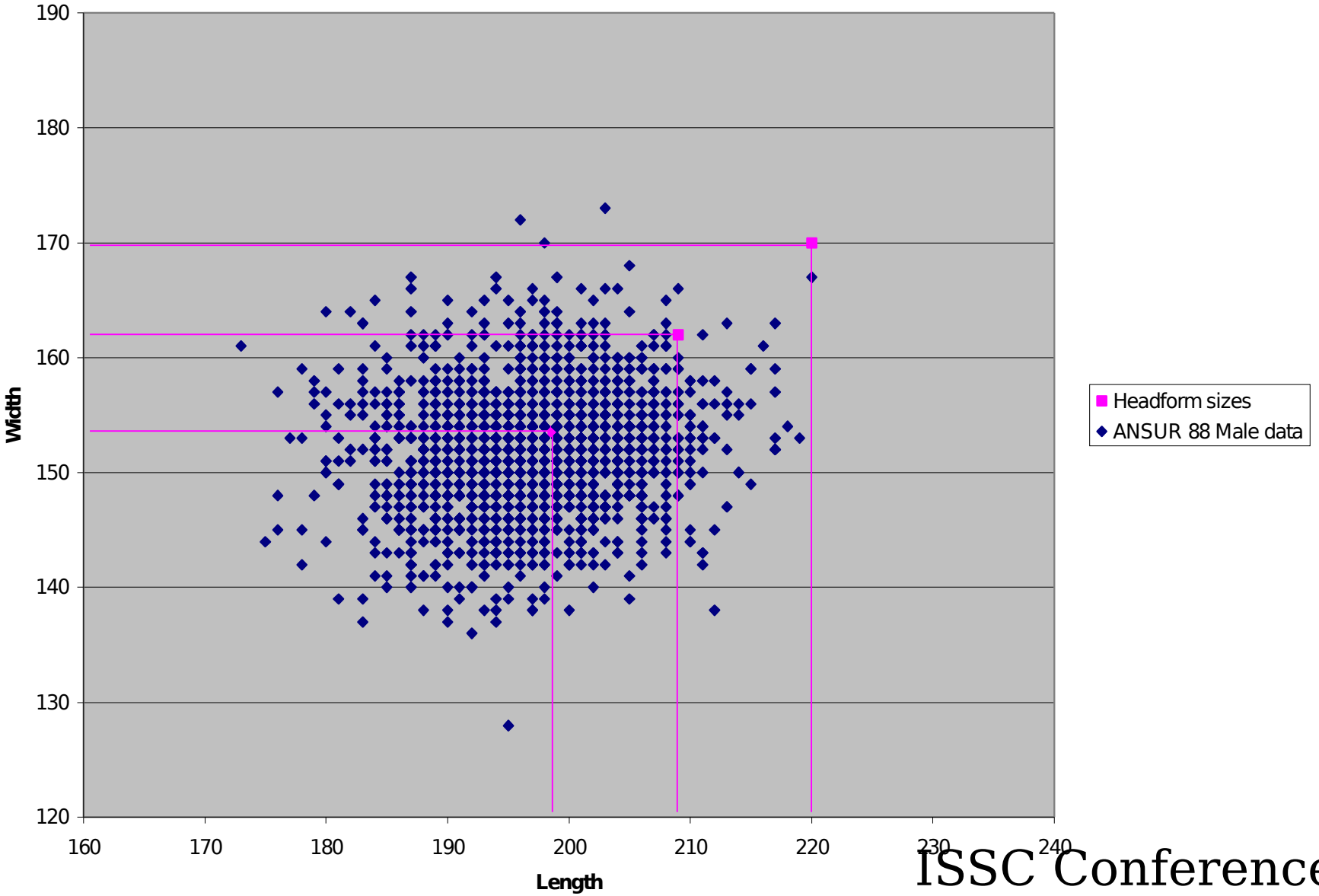
Shape Discrepancy Predictions for new sizes (N=126)

	Predicted				
Actual	**Small**	**Medium**	**Large**	**Total**	**% Correct**
Small	29	9	0	38	76.3
Medium	9	64	1	74	86.5
Large	0	1	13	14	92.9
Total	38	74	14	126	**84.1**

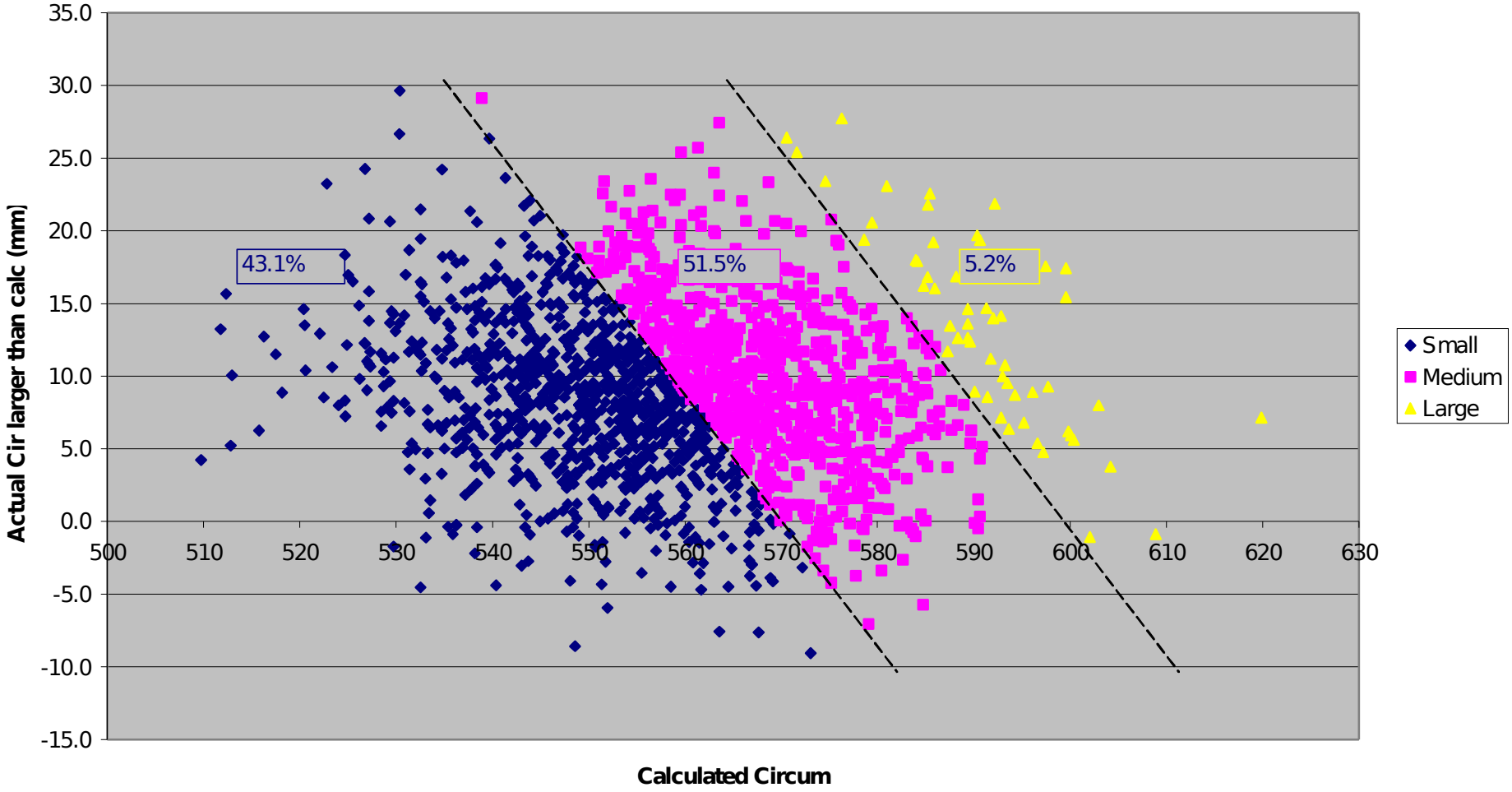
Actual = Predicted Distribution



Three sizes for ANSUR 88 data



Distribution of ANSUR 88 Population



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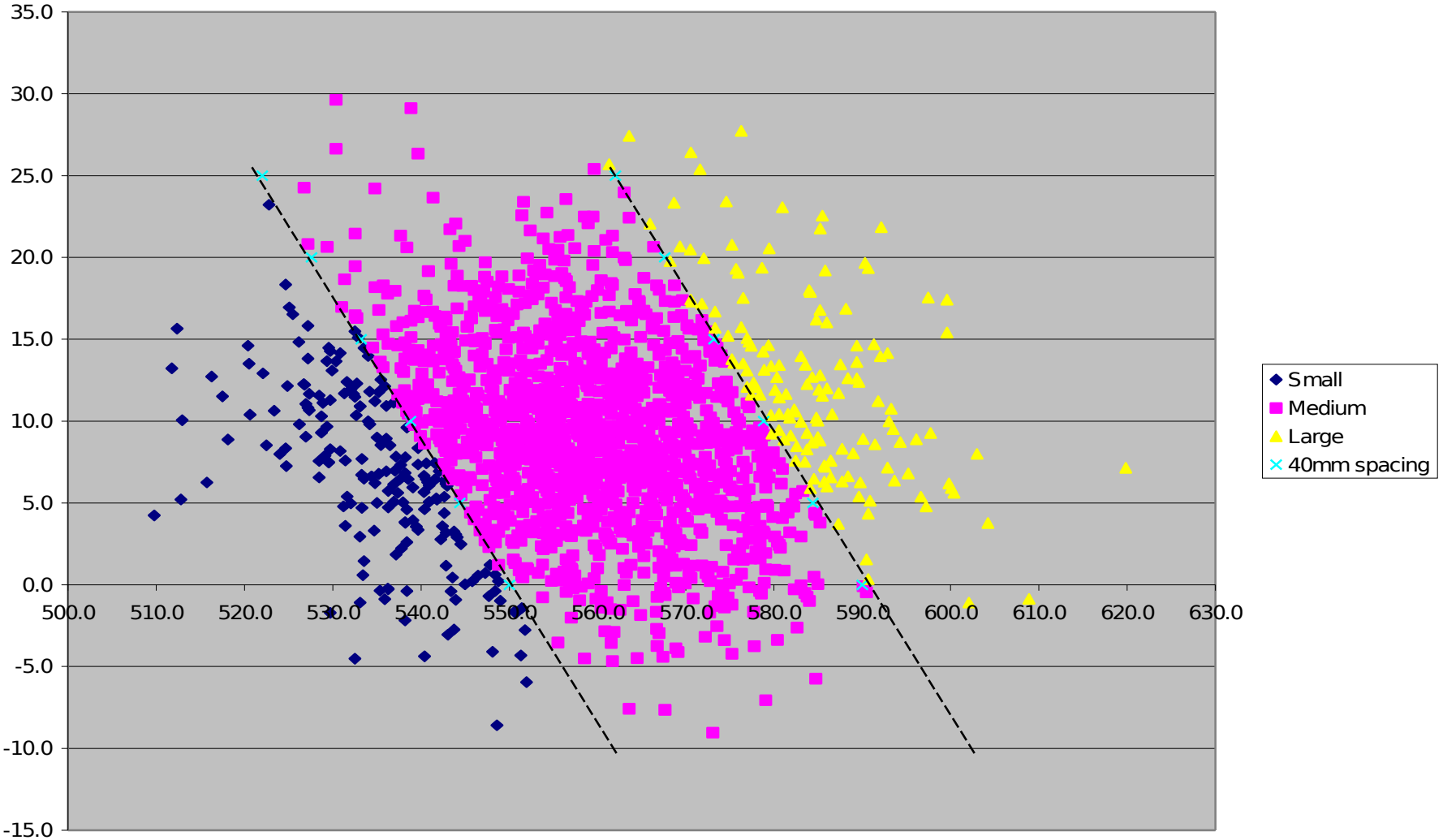
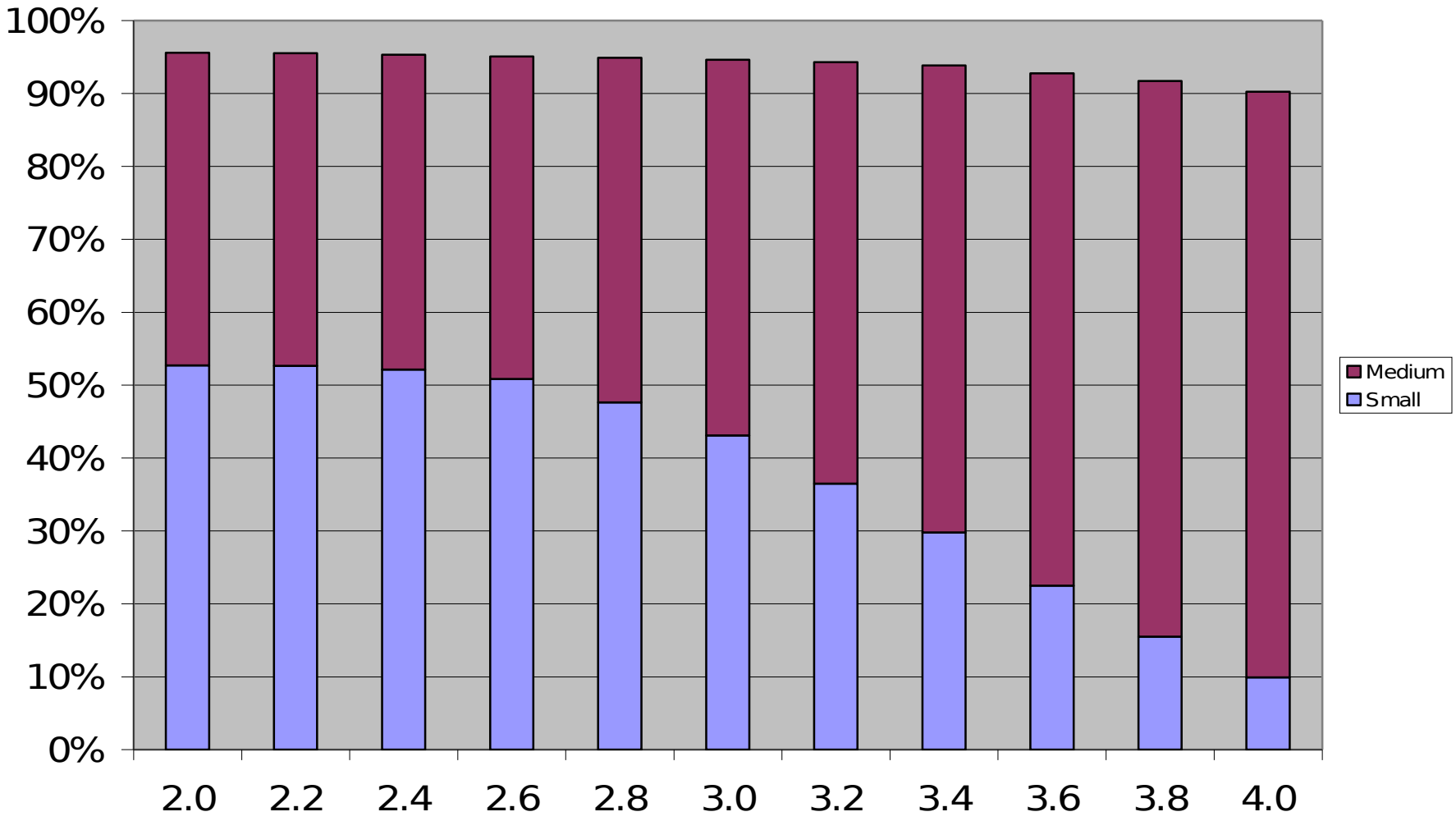
Spread sizes by 4.0 cm

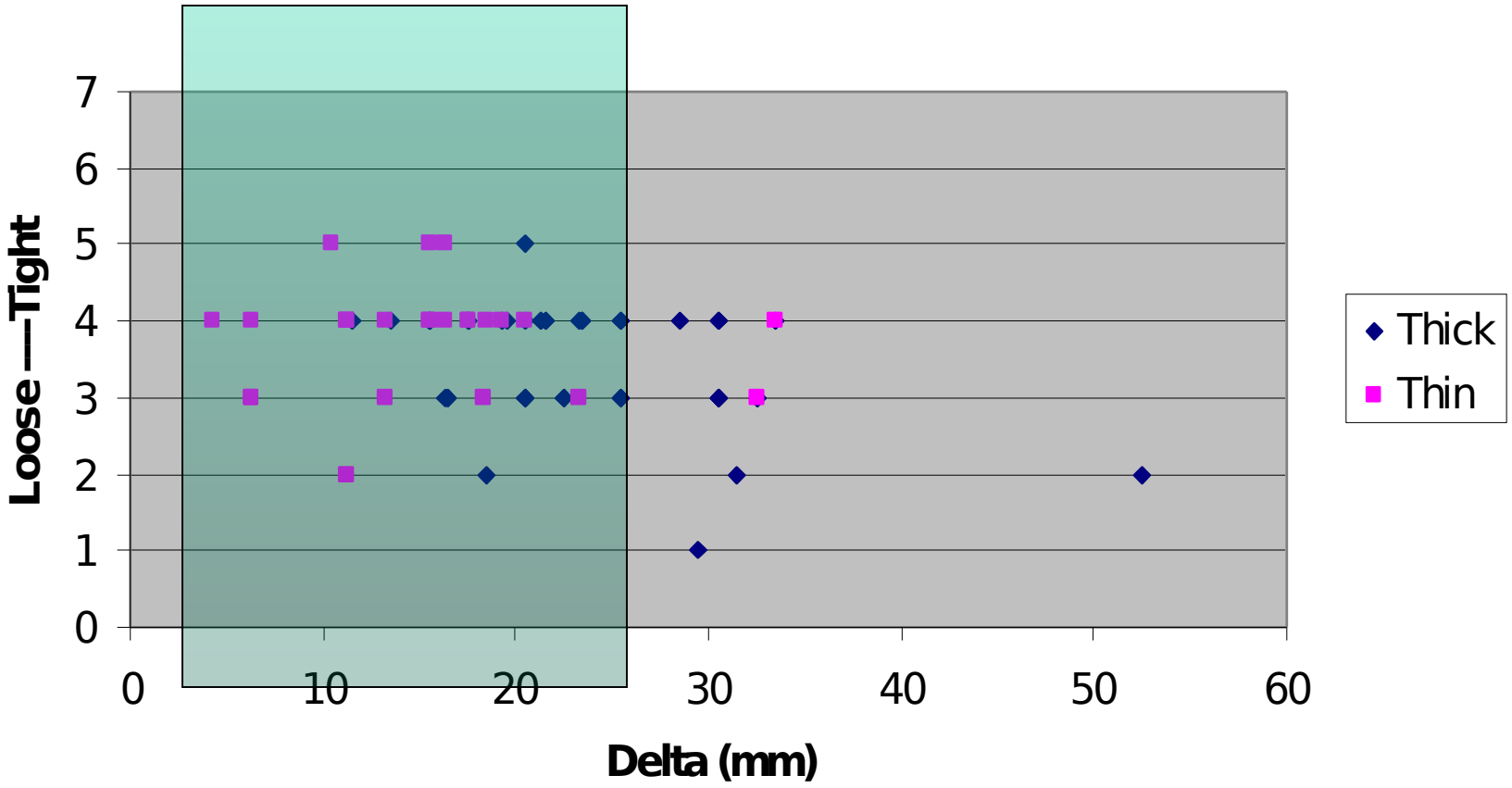


Percentage Wearing Each Size



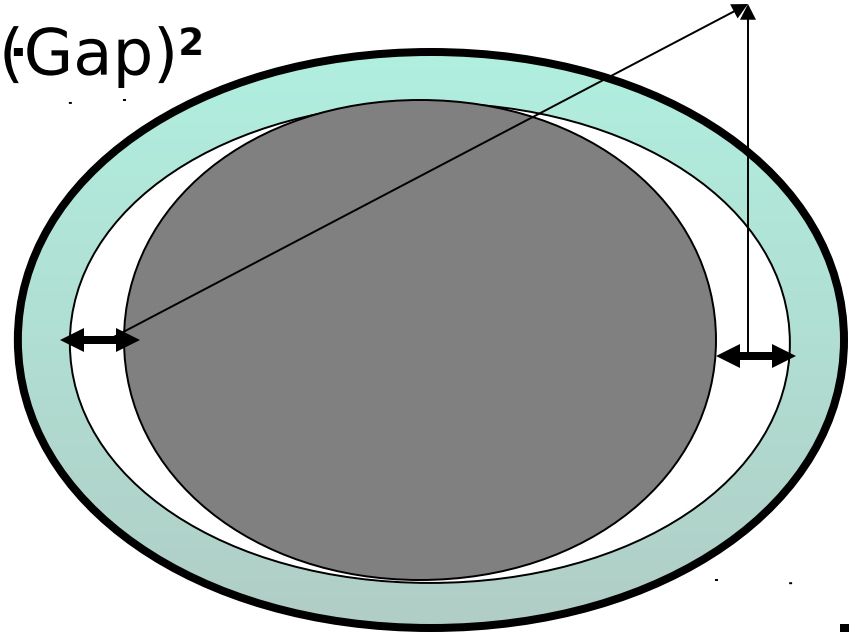
Spacing Between Sizes (cm)

Preferred Delta (Length)



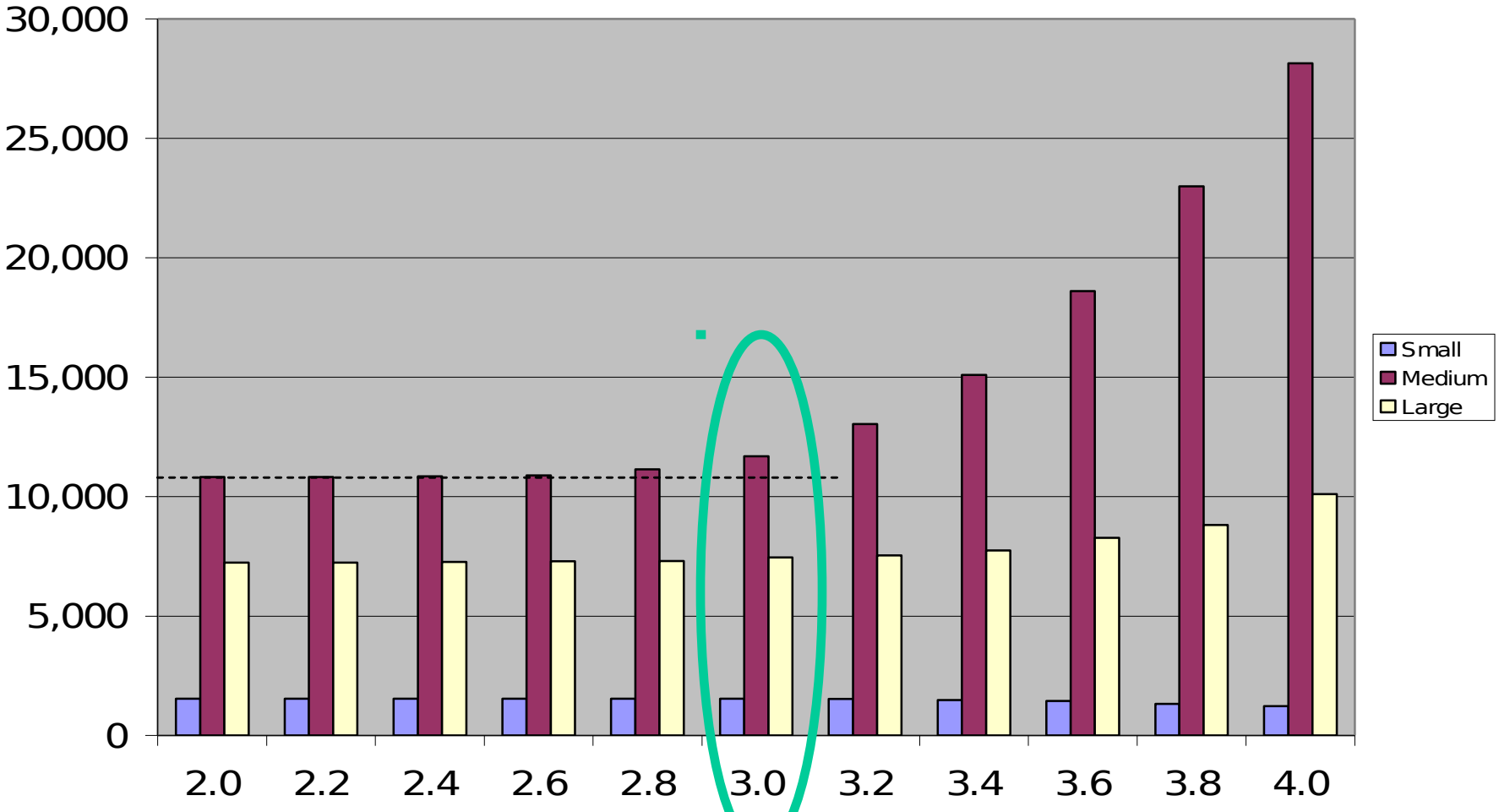
Estimation of Good / Poor Fit

Helmet Poor Fit Error = (Gap)²



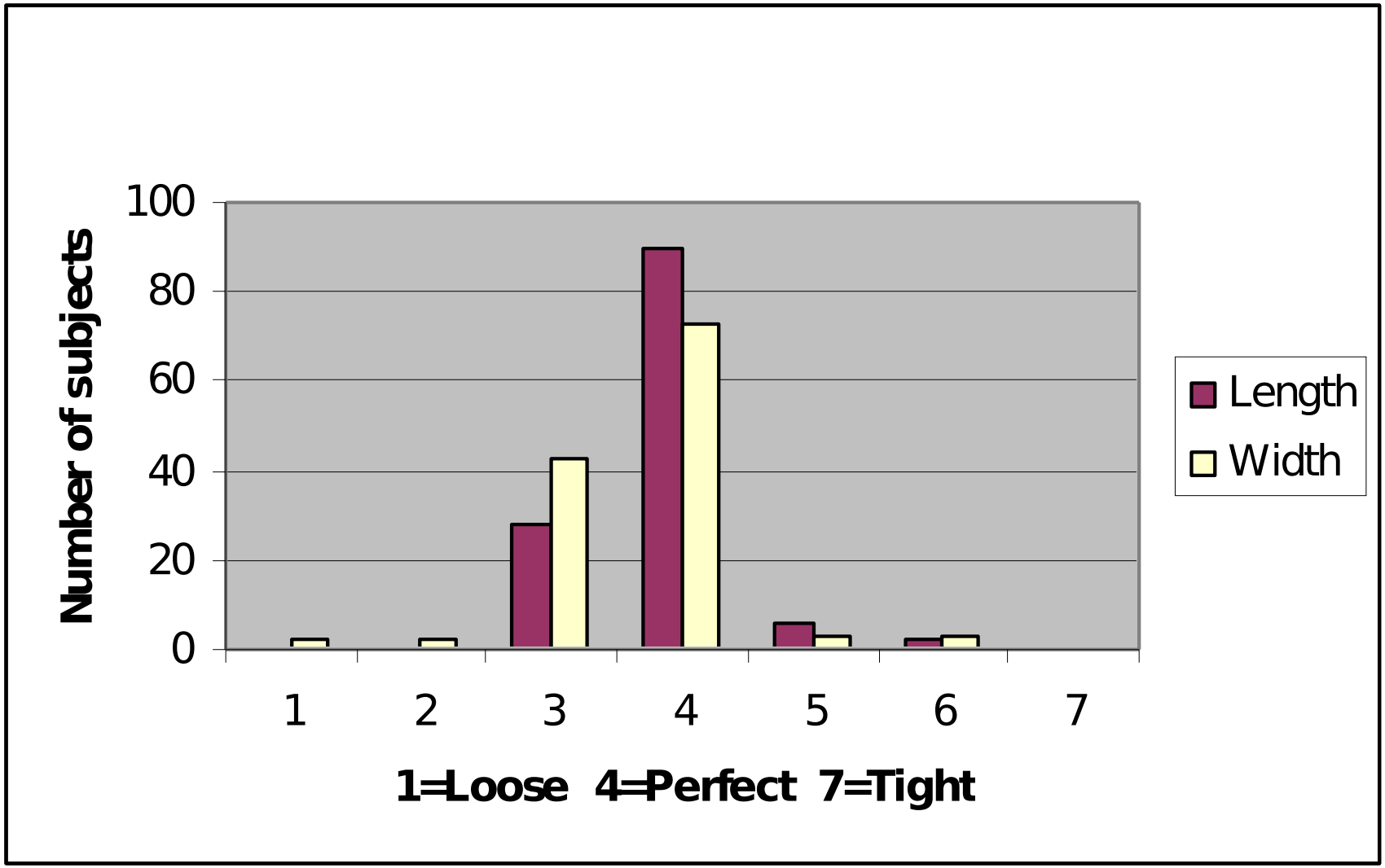
Population Poor Fit = Sum of All (Gap)²

Sum Sq Fit Errors



Spacing Between Sizes (cm)

Fit Scores all helmets



Summary

- Circumference is not a good indicator of helmet size
- Shape discrepancy calculation improves predictions
- The extent of accommodation of head shapes is dependent on helmet shape, retention system, and liner materials
- All of these must be considered when determining helmet sizing scheme

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- John Downey, Denny Langford, Camp MacKall
- Pierre Meunier, DRDC Toronto

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